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(54) HIGH VOLTAGE CABLE

(71) We, TELEFONAKTIEBOLAGET L. M. ERICSSON, a company organised under the laws of Sweden, of S-126 25 Stockholm, Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high voltage cables.

One known form of high voltage cable is as follows. An inner semiconductive layer is wound in the form of a tape, or is extruded, round a metal conductor and a layer of insulation, for example rubber or plastics material, is extruded over this inner layer. A screening part is thereafter applied concentrically over the insulation which part may consist of a semiconductive layer and a metallic earth return screen, whereby an even equipotential surface around the insulation is created in use of the cable. A close study of the currents in the cable shows that the outer semiconductive layer conducts a capacitive current across the layer in radial directions from the conductor to the surrounding screen. Furthermore, a resistive current appears in this layer, which current equalises voltages which appear circumferentially due to non-uniform field distribution. On the screening part, a surrounding cable sheath can be applied.

The inner semiconductive layer may be applied in the same operation as the insulation. Preferably, the outer semiconductive layer is also applied in the same operation, in a so-called triple extrusion process. The outer semiconductive layer then is strongly bonded to the insulation material.

Alternatively, the outer semiconductive layer may be manufactured by tapes, which are directly applied on the insulation, or as a layer painted or sprayed on to the insulation with semiconductive tapes on the painted or sprayed layer. Another method is to extrude on to the insulation a sheath of, for example, semiconductive rubber which tightens around the insulation.

Hitherto, is has been necessary to remove a length of such a metallic earth return screen and the outer semiconductive layer between a connection point and the free end of the screen when terminating or jointing the cable, high longitudinal field strengths appearing at the screen edge. If the outer semiconductive layer is such that it can be readily removed for terminating or jointing the cable, for example if it is formed by loosely applied semiconductive tapes, then there is a greater risk of damaging the cable as a result of stress in the use of the cable, but if the outer semiconductive layer is strongly bonded to the insulation, for example as a result of a triple extrusion process, then there is the problem of removing all of it between the connection point and the screen edge when preparing the cable for termination of jointing.

According to this invention, there is provided high voltage cable including a conductor, insulation around the conductor, and a semiconductive layer around the insulation, the semiconductive layer having an electrical surface resistivity measured along its outer surface of greater than 10^{6} ohm/square, and being strongly bonded to the insulation.

The insulation may be of synthetic material and preferably the semiconductive layer is of synthetic material.

Preferably, the said electrical surface resistivity is substantially voltage independent.

The semiconductive layer may comprise insulating material, for example polyethylene, with an admixture of conductive material, for example carbon.

The said electrical surface resistivity may, for example, have a value which does not exceed 10^{10} ohm/square, being preferably in the range of 10^{7} to 10^{9} ohm/square.

There may be another semiconductive layer, easy to remove, around and in

contact with the first-mentioned semiconductive layer, the other semiconductive layer having an electrical surface resistivity measured longitudinally along its outer surface not exceeding 10^6 ohm/square. The other semiconductive layer may be, for example, of paper, textile or synthetic material.

An example of the invention will now be described with reference to the accompanying drawings, in which:—

Figure 1 shows a high voltage cable construction, and

Figure 2 shows voltage distribution curves as a result of terminating or jointing of different cables, beneath a longitudinal section through the cable of Figure 1 prepared for termination or jointing.

The example is of a single core cable, but the invention is in essence applicable to a single core of a multiple core cable.

In the cable shown in Figure 1, an inner conductor is designated by 1, which conductor consists of, for example, twisted and packed wires. Outside this, an inner semiconductive layer 2 is applied in the form of semiconductive tapes or extruded semiconductive material to equalise the voltage stresses in the inner zone of surrounding insulation from the individual wires of the inner conductor. Reference 3 designates this insulation which consists of, for example, polyethylene material having a thickness which is determined by the rated voltage of the cable. Outside the insulation 3, an outer semiconductive layer 4 is applied, usually by extruding and subsequent vulcanisation. Usually, the surface resistivity, measured along the outer surface thereof, of the outer semiconductive layer has been 10^2 to 10^4 ohm/square. Thereby, a field pattern in the cable is obtained which shows small voltage gradients circumferentially despite the occurrence of a non-uniform field distribution, for example as a result of transient processes (bursts of thunder and the like). Calculations show, however, that the surface resistivity of the layer can be increased considerably more than these usual values, namely to a value greater than 10^6 ohm/square, for example 10^7 ohm/square. Thereby, the advantages of the layer as a field equalising resistance are essentially maintained but certain further advantages will be attained when terminating the cable, as will be more closely described in connection with Figure 2.

The outer semiconductive layer can consist, for example, of polyethylene material containing admixtures of carbon, for example carbon black, to obtain the desired resistivity. The outer semiconductive layer is strongly bonded to the insulation 3, and may be applied suitably by extrusion, preferably at the same time as the layer 2 and the insulation 3 in a triple extrusion process. Alternatively, the outer semiconductive layer may be applied by means of continuous lacquering. For example, the layer can be applied by spraying, dipping or by electrostatic painting so as to be strongly bonded to the insulation. An extrded outer semiconductive layer can be of elastomeric material, thermoplastic material or cross-linked (vulcanised) plastics material. The semiconductive layer 4 can have applied to it an extra layer 5 of semiconductive plastics material, textile, synthetic fibre or the like having a surface resistivity measured along its outer surface not exceeding 10^6 ohm/square. This outer material should be easy to remove during preparation of the cable shown for termination or jointing.

Referring now to Figure 2, in the cable prepared for termination or jointing, above the graph, the inner conductor is designated again by 1, on which the inner semicondutive layer 2 is applied. On the insulation 3 the outer semiconductive layer 4 is situated and in order to discharge the field currents to earth a metallic screen 6, for example of copper wire, is applied over the extra semiconductive layer 5. U_o designates the potential of the conductor, for example $12/\sqrt{3}$ or $24/\sqrt{3}$ kV, the screen having the potential O. For terminating or jointing the cable, a length of the screen is removed together with a length of the extra semiconductive layer 5, so that a length l of the end part of the outer semiconductive layer 4 is uncovered. Furthermore, part of the inner semiconductive layer and the insulation has been removed, so that the conductor 1 is uncovered at the extremity of the cable. The outer semiconductive layer 4 is brought into electrical contact with the conductor at the free end of the cable, for example by applying some layers of semiconductive tape 8. Of interest is the voltage distribution which arises in the outer semiconductive layer along the length between the screen 6 and the inner conductor 1. At too high a voltage gradient, an undesired glow discharge might arise during standard prescribed voltage tests. Such glow discharge can arise at the screen edge of hitherto proposed cable constructions, i.e. at the edge which is formed when layers of covering are removed from the conductor, unless special measures are taken. With the cable of Figure 1, little of layers 2, 3 and 4 is removed and, in particular, layer 4 continues to fulfil its function to equalise the longitudinal field between the outer screen 6 and the inner conductor 1. From

the graph, it appears that by means of semiconductive layer 4 having an electrical surface resistivity (ρ) measured along its outer surface of greater than 10^6 ohm/square, a substantially even voltage distribution along the length l of cable may be obtained. The graphs are shown for different values of the said resistivity, and for a certain value $\rho=10^7$ ohm/square an approximately linear voltage distribution can be obtained. With a layer of lower resistivity, i.e. between the values 10^2 to 10^4 ohm/square, too great a power development in the outer semiconductive layer would be obtained. In practice, local currents of high intensity and discharges because of them could arise as a consequence that such a semiconductive layer is not completely homogeneous.

WHAT WE CLAIM IS:—

1. High voltage cable, including a conductor, insulation around the conductor, and a semiconductive layer around the insulation, the semiconductive layer having an electrical surface resistivity measured along its outer surface of greater than 10^6 ohm/square, and being strongly bonded to the insulation.

2. Cable according to claim 1, wherein the insulation is of synthetic material.

3. Cable according to either of claims 1 and 2, wherein the semiconductive layer is of synthetic material.

4. Cable according to any of the preceding claims, wherein the said electrical surface resistivity is substantially voltage independent.

5. Cable according to any of the preceding claims, wherein the semiconductive layer comprises insulating material with an admixture of conductive material.

6. Cable according to claim 5, wherein the insulating material is polyethylene.

7. Cable according to either of claims 5 and 6, wherein the conductive material is carbon.

8. Cable according to any of the preceding claims, wherein the said electrical surface resistivity does not exceed 10^{10} ohm/square.

9. Cable according to claim 8, wherein the said electrical surface resistivity is in the range of 10^7 to 10^9 ohm/square.

10. Cable according to any preceding claim, wherein there is another semiconductive layer, easy to remove, around the first-mentioned semiconductive layer and in contact with it, the other semiconductive layer having an electrical surface resistivity measured along its outer surface not exceeding 10^6 ohm/square.

11. Cable according to claim 10, wherein the other semiconductive layer is of paper, textile, or synthetic material.

12. Cable according to any preceding claim, wherein the first-mentioned semiconductive layer was applied by continuous extrusion on to the outer surface of the insulation.

13. Cable according to claim 12, wherein the insulation was applied by continuous extrusion on to the outer surface of an inner semiconductive layer, itself applied by continuous extrusion, the inner semiconductive layer, the insulation and the first-mentioned semiconductive layer having been extruded at the same time, in a triple extrusion process.

14. Cable according to any of claims 1 to 11, wherein the first-mentioned semiconductive layer was applied by continuous lacquering on to the outer surface of the insulation.

15. Cable according to claim 14, wherein the first-mentioned semiconductive layer was applied by continuous spraying, dipping or electrostatic painting.

16. High voltage cable, substantially as herein described with reference to Figure 1 of the accompanying drawing.

17. A joint between two cables as defined by any preceding claim, or a termination of such a cable, in which a substantial length of the first-mentioned semiconductive layer is left exposed on the or each cable and is electrically connected to the conductor at the end of the layer.

18. A joint or termination according to claim 17, wherein the electrical connection is formed by tapes of semiconductive material.

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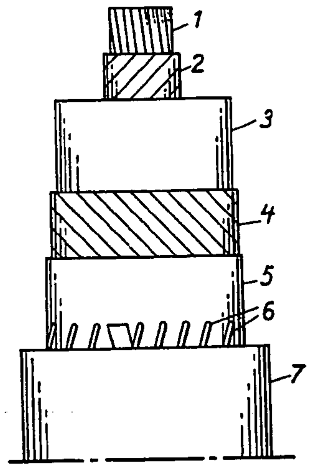

Fig.1

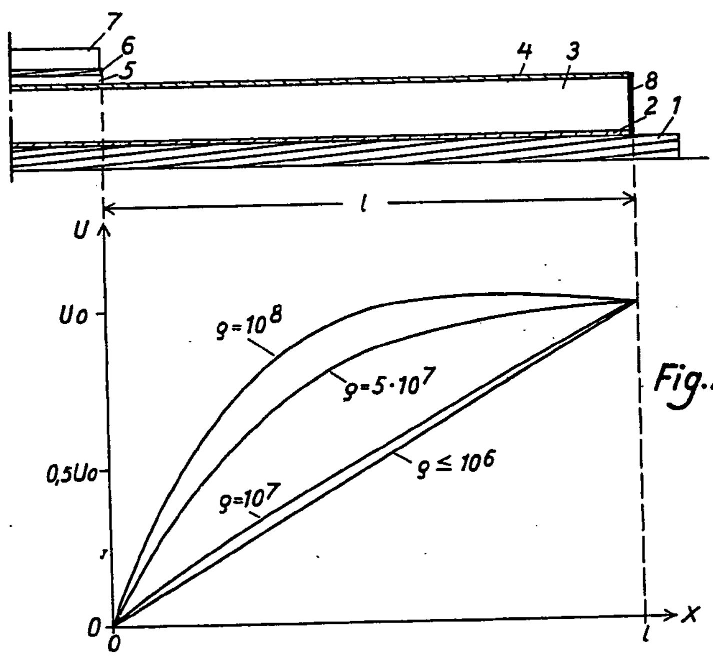

Fig.2